CONTRIBUTION OF SMALL-SCALE BIO-OPTICAL AND BIO-ACOUSTICAL DISTRIBUTIONS AND VARIABILITY TO UPPER OCEAN PROCESSES

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LONG-TERM GOALS

Our long-term goal is to quantify the interactions between small-scale biological and physical processes within the upper ocean. This project has addressed that goal by examining specific scientific questions which relate the distribution and variability in sub-1m scale bio-optical properties with coincident spatial scales of physical properties.

OBJECTIVES

Our scientific objective has been to obtain time series profiles which document the vertical patterns of bio-optical distribution and variability in several coastal oceanic habitats. We have accomplished this objective by integrating newly developed bio-optical and bi-acoustical instrumentation with a CTD into a free-fall package which resolves physical, optical, and biological features over vertical scales of 1-3 cm, and bio-acoustic features over vertical scales of 20 cm. The profiler gives us the opportunity to address several important questions about bio/physical interactions on the small-scale. For example, what are the dominant time scales of persistence of small-scale planktonic structure? Are all bio-optical properties correlated within persistent small-scale features? How is the grazer biomass (based on high-frequency acoustic backscattering) distributed relative to the thin layers of phytoplankton biomass? Do aggregations of small grazers occur with particular "types" of thin layers? Under what range of physical and biological conditions do we observe correlations between thin layers of phytoplankton and small

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grazer biomass? What is the potential benefit to small grazers of spending some proportion of time within thin layers of phytoplankton biomass? To what extent can persistent planktonic features be predicted from physical processes? What are the consequences of intense small-scale planktonic structure on optical and acoustical signal attenuation?

This work supported by ONR Biological Oceanography and Ocean Optics.

APPROACH

We address the objectives and questions outlined above through time-series deployments of our free-fall profiling system. The instrumentation package has an adjustable fall speed so that we can resolve vertical patterns on scales less than 10 cm. Typically, we adjust the buoyancy on the profiling package to provide 2-3 cm resolution of physical and bio-optical properties during each profile. Repeated profiles (approximately 10 per hour) provide the time series necessary to define the temporal patterns of persistence of small-scale features. The profiling package is designed so that the instrumentation configuration can be modified easily. Typical deployment configurations have consisted of a Sea-Bird 911 CTD, ac-9 (2), SAFIRE, and MODAPS (data system).

WORK COMPLETED

Field work in Puget Sound, WA, and off the Oregon coast, has resulted in several time-series of profiles under a range of physical forcing conditions. We have developed data merging protocols for multiple instruments on the profiling package (each instrument has a unique data acquisition rate). We hosted a data analysis workshop and field experiment planning meeting for all PIs involved with the small-scale structure field work in Puget Sound, WA. Our separate DURIP support has permitted us to expand our instrumentation suite and include additional bio-optical sensors and horizontal velocity sensors on the profiling system. In collaboration with Dr. Van Holliday, we have incorporated a small-scale bio-acoustics system for detection of 20-30cm scale aggregations of zooplankton.

RESULTS

We have observed sub-1m scale structure in bio-optical properties in all oceanic habitats examined. While many of these small-scale patterns are associated with local steep gradients in sigma-t, density structure alone does not account for the observed persistent small-scale patterns. We often observe spectral differences in small-scale vertical patterns of distribution of both particulate and dissolved components, suggesting considerable taxonomic and physiological variability between nearby layers of plankton. The results from all habitats examined to date suggests that 20-40cm thick layers of plankton are common features of the upper ocean, and persistent layers (time scales of 2-8 hrs) occur near the base of the surface mixed layer and within and below the thermocline. In the profiles obtained to date, about 75% of the small-scale structures (layers) occurred within the euphotic zone, indicating that both growth and removal terms must be considered when evaluating the impact of persistent features on local trophic dynamics. The combined use of high data rate, high-resolution physical, bio-optical and bio-acoustic instrumentation on free-falling profilers has provided us with unique capabilities to detect patterns in physical and biological structure over small spatial and short temporal scales. Time series of profiles then reveal which components of the observed pattern persistent in time and space.

IMPACT

Our results suggest that additional direct assessment of the trophic implications of persistent thin layers is needed, with particular emphasis on the potential for enhanced grazing, steeper local gradients in nutrient flux and regeneration, and variations in particle flux from the euphotic zone. Our work with biological microstructure suggests that previous observations of small-scale biological patchiness may not have been observations of stochastic fluctuations in biological structure (i.e., patchiness), but under-sampled observations of persistent, small-scale structure. Centimeter-scale organization of planktonic biomass forces a re-evaluation of water column rate processes, and challenges our existing paradigms for sampling and experimentation over scales of meters and 10's of meters.

TRANSITIONS

We are making the transition from observations of small-scale pattern to analysis of the mechanisms which create that persistent pattern. This will be essential for prediction of the impact of persistent small-scale pattern on the attenuation of optical and acoustic signals in the upper ocean.

RELATED PROJECTS

Our ongoing work has led to direct field collaborations with the following ONR Principal Investigators:

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Dr. Jan Rines, University of Rhode Island
Dr. Dian Gifford, University of Rhode Island
Dr. Alice Alldredge, UC Santa Barbara
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Dr. Mary Jane Perry, University of Washington
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